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A STUDY OF THE EFFECTS OF SAGEBRUSH REMOVAL ON
CERTAIN WATERSHED CHARACTERISTICS

Ronald D. Tabler

FINAL REPORT

"A Study of the Effects of Sagebrush Removal
on Certain Watershed Characteristics"

Study No. 302

Rocky Mountain Forest and Range Experiment Station
Forest Service, USDA

Prepared by

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INTRODUCTION

This report summarizes results from "A study of the effects of sagebrush removal on certain watershed characteristics" (Study No. 302). Begun in 1959 as the first effort of what was then the newly established watershed research project in Wyoming (FS-RM-1603), this study employed three small contiguous watersheds on the Wind River District of the Shoshone National Forest.

At the time this study was established, sagebrush spraying was enjoying considerable popularity as a means of increasing usable forage; it seemed important to assess the hydrologic effects of this management practice.

After 6½ years of pretreatment calibration, one watershed was sprayed with 2,4-D in 1965. By the end of 1971, study objectives had been accomplished, and it appeared little was to be gained with further measurements. Consequently, a recommendation for termination was submitted to the Director's Office in April 1972, with a brief summary of results. This recommendation received concurrence, and measurements were discontinued effective the end of the 1971 water year.

This document is a final report on the study, and will provide the basis for a technical publication.

THE STUDY

Objectives

Objectives as set forth in the original study plan were

"...to determine the effects of big sagebrush on

1. Total runoff from snow melt

2. Total snow accumulation and storage pattern.

In addition to these major objectives, the study offers opportunity to determine how natural stands of sagebrush affect cloudburst storm runoff and rate of sediment movement from spring snowmelt. Also, a measure of changes in ground cover and herbage production following eradication of sagebrush will be possible, and certain big game relationships will be studied."

Study Area

Three contiguous drainages, 60, 66, and 106 acres, were selected for study near Castle Rock in the Wayne's Creek drainage, Wind River District, Shoshone National Forest (S 10 & 11, T43N, R105W). Elevations range from 9,500 to about 10,000 feet, and drainage is generally southward (Fig. 1). Slopes, predominately east- and west-facing, are moderate. Vegetation is dominated by mountain big sagebrush (Artemisia tridentata subsp vaseyana (Rydb.) Beetle), with densities of 8,000 to 10,000 plants per acre. Open grassland constitutes the second most important cover type (Table 1).

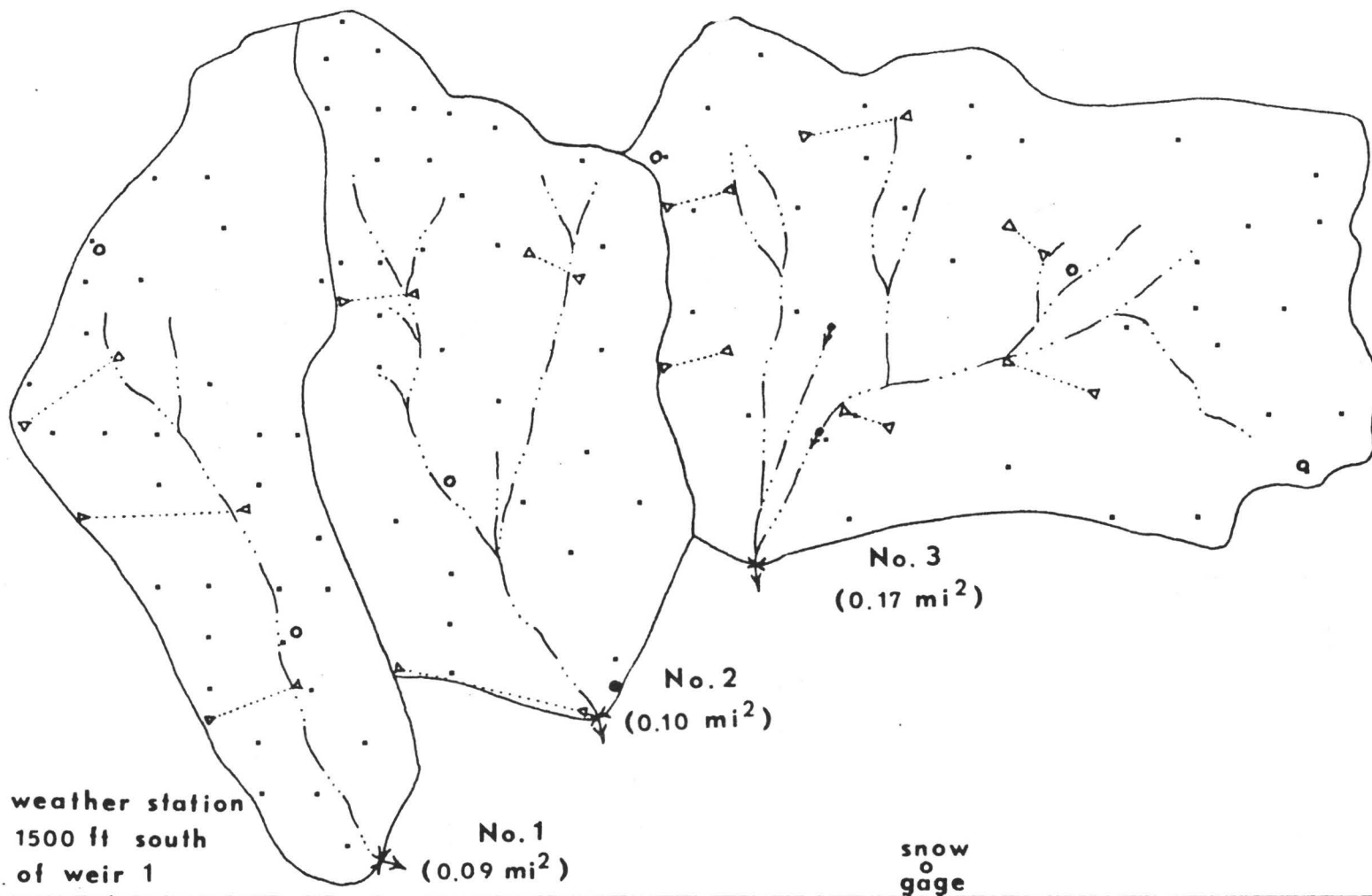
Table 1. Percent area occupied by cover types

Type	Watershed 1 (61 acres)	Watershed 2 (66 acres)	Watershed 3 (106 acres)
Sagebrush	69	75	60
Willow	0	2	2
Shrubby cinquefoil	1	0	1
Grass	28	24	33
Wet meadows	2	0	1
Englemann spruce	0	0	4

Herbage production is about equally divided among the four classes: Idaho fescue (Festuca idahoensis), "other grasses," lupine (Lupinus spp.), and "other forbs." Soils, developed in place or of glacio-fluvial origin, are derived from the volcanic conglomerate Tepee Trail formation, and are predominately sandy clay loams. Soil depth ranges from exposed parent rock to more than 9 feet, but average soil depth is believed to be 4 to 5 feet.

The study area is within the Bear Creek allotment, and has been grazed by cattle for many years. The area is also used by elk in late fall and early spring.

Average annual precipitation is about 20 inches, two-thirds of which is received as snow. All three streams are intermittent, with nearly all flow originating as snowmelt.



WAYNE'S CREEK WATERSHEDS WYOMING

USDA Forest Service, Rocky Mountain Forest
and Range Experiment Station

Scale: 100's of feet
0 2 4 6 8 10

- X stream gage
- o standard rain gage
- recording rain gage
- Δ snow course
- ⚡ spring
- sampling point for snow,
soil moisture, vegetation

Figure 1.

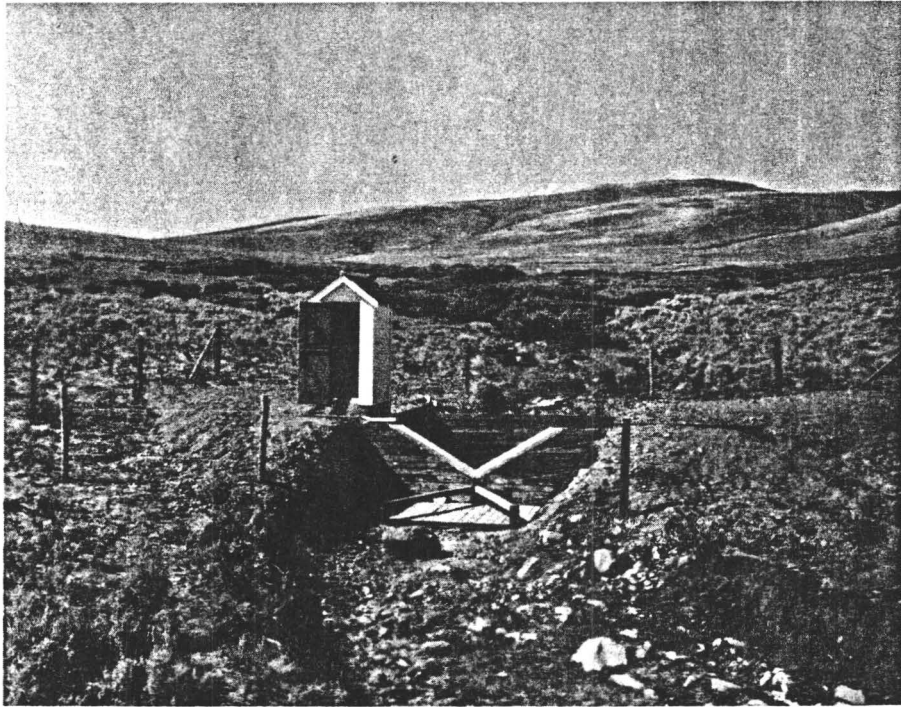


Figure 2. Watershed 2 streamgage, with 120° v-notch weir.

Cutoff wall is redwood. 1959.

Study History

- 1958: Study area selected by Marvin D. Hoover and Wallace M. Johnson, both of the Rocky Mountain Forest and Range Experiment Station. Partial construction of weirs by the Shoshone National Forest.
- 1959: Completion of stream gages, installation of all instruments and permanent plots. All measurements initiated with the exception of ground cover. Calibration begun. Project personnel: H. W. Berndt and R. D. Tabler.
- 1961: Study area fenced, with grazing regulated at about 50 cow-months. Ground cover measurements initiated.
- 1963: Area withdrawn from mineral entry by Order No. 2978 per Executive Order 10355.
- 1965: Watershed 3 sprayed with 2,4-D (2 pounds acid-equivalent per acre), by helicopter, on June 29. New road built into study area. Livestock grazing excluded. Treatment phase begun.
- 1971: All measurements discontinued as of October 1, 1971.
- 1972: Memorandum to Assistant Director recommending termination of study (4300, April 5). Concurrence May 17. Area reopened to livestock grazing.

Methods

All data collection was accomplished in accordance with the study plan and its amendments. An outline of the more important instruments and sampling techniques follows:

Streamflow.--Sharp-crested V-notch weirs (90° on Watershed 1 and 120° on Watersheds 2 and 3) were installed on each of the three watersheds (Fig. 2); these were equipped with Stevens A35 water stage recorders. Streamgages were opened before the onset of snowmelt each year, and operated until about October 1.

Precipitation.--A standpipe-type precipitation gage, equipped with alter shield, was operated year around in a small forest opening about 1,000 ft east of the weir on watershed 3. A single unshielded recording gage was operated during the summer months (about June 1 to October 1) at a site near weir 2. Summer precipitation was also sampled with a network of two pit-type storage gages on each watershed (Fig. 1).

Snow.--Snow measurements were taken at two- to four-week intervals each spring beginning in mid-March, and continuing up to the time of peak accumulation. Twelve permanent transects, ranging from about 200 to 750 ft in length, were established across areas of natural accumulation (usually on east-facing slopes) (Fig. 1). Snow depths were probed along these transects at 25-ft intervals. Snow densities (water-equivalent) were sampled at 25-ft intervals along one transect on each watershed, using a Mt. Rose sampler. In addition, snow depths were measured at each of the 96 permanent sampling points used for vegetative measurements (Fig. 1).

Soil Moisture.--From 1959 to 1965, gravimetric samples for soil moisture were collected each fall from 18 randomly selected locations

on each watershed. Using a Viehmeyer (King) tube, samples were separated into 0-2 and 2-4 ft depths.

Sediment.--Dip samples for suspended sediment were collected from all three watersheds in an attempt to characterize daily rising and falling stages as well as seasonal trends. These measurements were discontinued in 1967. Coarse sediment accumulation was determined by cross-sectioning the weir ponds each fall. Bulk density samples were collected in 1966.

Vegetative Measurements.--Each watershed was stratified by the generally east and west exposures lying on either side of the main stream channels. Within each stratum, sixteen sampling points were selected at random, and permanently marked by 6-ft steel posts. Paired 2-ft by 2-ft plots were permanently marked 25 ft northwest and southeast of these reference stakes. Herbage production was estimated near the first of August each year on each of these permanent plots (64 on each watershed), using a double-sampling technique. Production estimates were divided into the classes Idaho fescue, Poas, "other grasses," lupines, and "other forbs." Ground cover (basal area) was also measured each August using a 100-pin point quadrat device. Hits were recorded on the same classes used for herbage production, in addition to the cover conditions "bare," "rock," "litter," and "live sagebrush" (both basal and aerial hits).

Utilization by Livestock and Game.--During the pretreatment phase, utilization (percent by weight) by livestock was estimated on each

permanent plot at the end of each growing season. An indication of elk use was obtained by counting the number of pellet groups each spring on 1/100 acre circular plots superimposed on each 4-sq-ft plot used for vegetative measurements.

RESULTS

Hydrologic Characteristics

Precipitation.--Excluding 1959, mean water-year precipitation was 20.5 inches, 64% of which was received as snowfall between October 1 and June 1. The lowest water-year total was 15 inches in 1969, and the highest was 31 inches in 1965 (Table 2). Summer precipitation, as measured with the Thiessen network of six pit gages, was very nearly the same on all three watersheds.

Snowpack.--As calculated from annual measurements at each of the 32 permanent points on each watershed, average snowpack water-equivalent at time of peak accumulation was 8.2, 9.0, and 6.7 inches, on watersheds 1, 2, and 3, respectively (Table 3). The lowest average over all three watersheds was 4.4 inches in 1961, and the highest was 15.4 inches in 1965. Peak accumulation was attained between March 15 and April 30, with April 1 the typical date.

Topography is the dominant factor influencing snow accumulation, with drift depths exceeding 12 ft in the more favorable areas on east-facing slopes. Figure 3 shows panoramas of the study area, looking west, typifying snow cover conditions at the time of peak runoff (commonly in mid-May). Ridges are typically blown free of snow throughout the winter, and accumulations on west-facing slopes are characteristically shallow.

Because topography dominates the accumulation pattern, it is not surprising that spraying the sagebrush did not have any detectable effect on total snowpack water-equivalent (Fig. 4).

Table 2. Precipitation at the Dubois study area, in inches

Water year	(1) Total W.Y. precip.	(2) Summer precip. (6/1-10/1)	(3) Precip. from 10/1 to peak snowpack	(4) Precip. from peak snowpack to 6/1	(5) Winter precip. (10/1-6/1)
1959	17.0 ^e	4.9 ^e	8.6 ^e	3.5 ^e	12.1 ^e
60	15.4	6.6	7.6	1.2	8.8
61	18.4	7.5	7.5	3.4	10.9
62	22.3	6.4	11.3	4.6	15.9
63	22.9	8.9	10.6	3.4	14.0
64	17.3	6.0	6.3	5.1	11.3
65	30.9	10.8	14.8	5.3	20.1
66	18.6	9.4	5.4	3.7	9.2
67	23.3	9.9	7.4	6.0	13.4
68	21.8	9.6	8.3	3.9	12.2
69	15.0	5.3	7.7	1.9	9.7
70	17.8	3.8	12.1	1.9	14.0
71	22.3	4.1	13.2	5.1	18.2
Means (60-71)	20.5	7.4	9.4	3.8	13.1

Column (1) = Col. (5) + Col. (2).

Column (2) = Mean of Thiessen net for the 6 standard pit gages.

Column (3) = Record from stand-pipe gage only.

Column (4) = Record from stand-pipe gage only, adjusted for service dates based on record from recording gage where possible.

Column (5) = Record from stand-pipe gage only, = Col. (3) + (4).

e/ 1959 values estimated by regression using 1960-68 data (n = 9).

For Col. (3), Snow Transect 1-2 vs. standpipe precip.

For Col. (4), Published record for USWB Thermopolis 25 WNW versus stand-pipe precip.

Table 3. Average snowpack water-equivalent (inches), at time of peak accumulation, based on weighted averages to the 32 permanent sampling points on each watershed.

Year	Date of peak accumulation	Water-equivalent			
		W/S 1	W/S 2	W/S 3	Means
1959	4-25	---	---	---	---
60	3-23	4.9	5.7	4.6	5.1
61	3-30	4.5	4.8	4.0	4.4
62	4-12	9.8	10.6	7.8	9.4
63	4-25	8.6	9.8	7.8	8.7
64	4-1	6.0	6.3	4.7	5.7
65	3-27	16.0	17.4	12.7	15.4
-- Treatment--					
66	3-13	6.0	6.5	5.0	5.8
67	3-15	7.6	8.9	6.3	7.6
68	3-27	6.1	6.6	5.5	6.1
69	3-27	7.5	8.4	5.6	7.2
70	4-28	10.0	10.4	8.4	9.6
71	4-6	11.0	13.1	7.9	10.7
Means		8.2	9.0	6.7	8.0

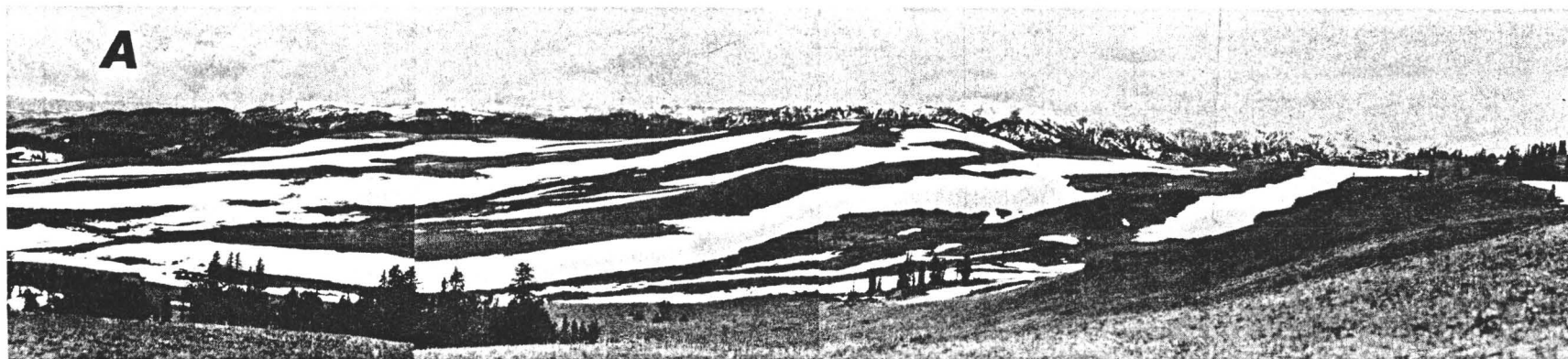


Figure 3. Typical snow conditions over the study area as viewed from the south boundary of Watershed 3.
(A) June 3, 1971, near the time of peak snowmelt runoff. (B) June 16, 1971, one week after the hydrograph peak.

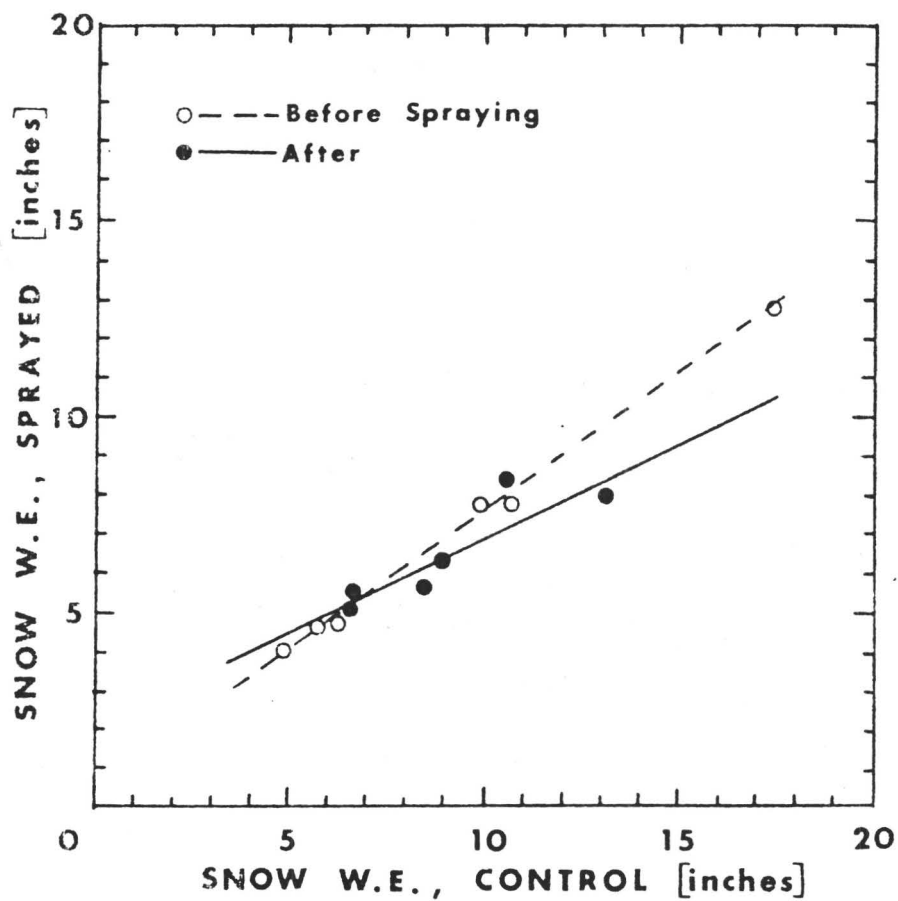


Figure 4. Snowpack water-equivalent (W.E.) at time of peak accumulation, sprayed versus control watersheds. Watershed 2 is used as the control.

Streamflow.--Mean annual flows from watersheds 1, 2, and 3 were 2.8, 3.9, and 3.7 inches, respectively (Table 4). Annual yields ranged from 0.35 inches on watershed 1 in 1959, to 10.7 inches from watershed 2 in 1965.

All three streams are ephemeral, with streamflow usually beginning in April. Flow typically ceased in late June on watershed 1, late July on watershed 2, and in late September on watershed 3. More than 90% of the total streamflow originated from snowmelt, with runoff during the months of April, May, and June accounting for about 96% of the average flow from the three drainages (Table 5). Averaged over all watersheds, streamflow was about 17% of the water-year precipitation, and accounted for about 27% of the winter's precipitation (Fig. 5).

Although total annual yield was about 13% greater after spraying than predicted by the pretreatment regression (Fig. 6), this increase was not significant at the 0.95 confidence level (Type II error = 0.80). In view of the relatively poor statistical sensitivity of the experiment, it is important to note that this magnitude of treatment effect agrees well with a plot study of soil moisture response to spraying, which showed soil moisture withdrawal on a site near the watersheds to be reduced about 14% of the third year after spraying (Tabler, 1968). Indeed, all of the requirements listed by Hill and Rice (1963) as being necessary for changes in soil moisture to be manifest in water yield are present on the study area (i.e., soils

deeper than 3 feet, sufficient precipitation each winter to completely recharge the soil mantle, and grass cover maintained free of weeds).

Because treatment had no discernible effect on late summer (July through September) streamflow (Fig. 7), it is concluded that any treatment effect on total annual yield must result from differential soil moisture deficits near the onset of snowmelt.

All peak instantaneous discharges, ranging from 4 to 55 csm (Table 6), resulted from snowmelt, as did all maximum daily flows (Table 7). Peak flows arising from summer convective storms never exceeded 7 csm, and the majority of summer storms resulted in peak discharges less than 1 csm.

There was no obvious effect of treatment on either peak instantaneous discharge (Fig. 8) or mean daily maximum discharge during snowmelt (Fig. 9).

All of the above results relating to streamflow are to be expected in light of snow cover characteristics, and the absence of significant treatment effects on this factor.

Table 4. Monthly streamflow (in area-inches) from the three study watersheds

Calendar		<u>Watershed 1 (60 acres)</u>					
<u>Year</u>	April	May	June	July	August	Sept.	Total
1959	0	0.08	0.27	0	0	0	0.35
60	1.20	1.22	0	0	0	0	2.42
61	0.27	1.22	0.01	0	0	0	1.51
62	4.04	2.02	0.25	0	0	0	6.31
63	2.64	0.83	0	0	0	0	3.47
64	0.04	2.24	0.32	0	0	0	2.59
65	0	0.27	4.46	0.03	0.01	0	4.77
66	0.54	1.75	0	0	0	0	2.29
67	0	3.19	0.60	0	0	0	3.79
68	0.02	1.43	0.30	0	0	0	1.76
69	0.87	0.58	0.05	0	0	0	1.50
70	0	1.31	0.16	0	0	0	1.48
71	0	2.26	1.80	0	0	0	4.07
Means	0.74	1.42	0.63	0.00	0.00	0.00	2.79

Table 4 (cont'd). Monthly streamflow (in area-inches) from the three study watersheds.

Calendar		Watershed 2 (66 acres)					
Year	April	May	June	July	August	Sept.	Total
1959	0	0.34	2.30	0.08	0	0	2.71
60	1.55	0.80	0	0	0	0	2.35
61	0.31	1.08	0.01	0	0	0	1.40
62	1.48	2.70	0.89	0.07	0	0	5.14
63	0	3.10	2.35	0.15	0.02	0.03	5.64
64	0.02	2.28	0.37	0.06	0	0	2.73
65	0	0.47	9.17	1.01	0.07	0.01	10.73
66	0.53	1.66	0.01	0	0	0	2.20
67	0	3.30	2.40	0.46	0.01	0.01	6.18
68	0.01	1.45	1.05	0.06	0.07	0	2.64
69	0.86	0.38	0.15	0	0	0	1.39
70	0	1.79	0.42	0	0	0	2.22
71	0	1.75	3.96	0.16	0.01	0.01	5.87
Means	0.37	1.62	1.78	0.16	0.01	0.00	3.94

Table 4 (cont'd). Monthly streamflow (in area-inches) from the three study watersheds

Calendar		Watershed 3 (106 acres)					
Year	April	May	June	July	August	Sept.	Total
1959	0	0.28	1.66	0.10	0.02	0	2.06
60	0.61	0.38	0	0	0	0	1.00
61	0.14	0.53	0.10	0.01	0	0	0.78
62	2.25	1.81	1.50	0.12	0.02	0	5.71
63	0	2.37	3.30	0.29	0.07	0.02	6.04
64	0.02	1.42	1.04	0.19	0.05	0.01	2.73
65	0	0.34	8.38	1.00	0.10	0.02	9.82
- - - - - Treatment on 6-29-65 - - - - -							
66	0.38	1.17	0.08	0.01	0.01	0.01	1.65
67	0	2.26	3.60	0.74	0.10	0.02	6.71
68	0.01	1.09	2.21	0.20	0.09	0.02	3.62
69	0.60	0.23	0.26	0.11	0.02	0	1.23
70	0	1.24	0.83	0.06	0	0.01	2.13
71	0	1.52	3.42	0.18	0.01	0	5.12
Means	0.31	1.13	2.03	0.23	0.04	0.01	3.74

Table 5. Mean monthly flow from the three watersheds, as percent of mean annual flow

Watershed	----- Month -----					
	April	May	June	July	August	Sept.
1	26.5	50.7	22.7	0.1	0.0	0.0
2	9.4	41.2	45.1	4.0	0.4	0.1
3	8.2	30.1	54.2	6.2	1.0	0.2
Means	14.7	40.7	40.7	3.4	0.5	0.1

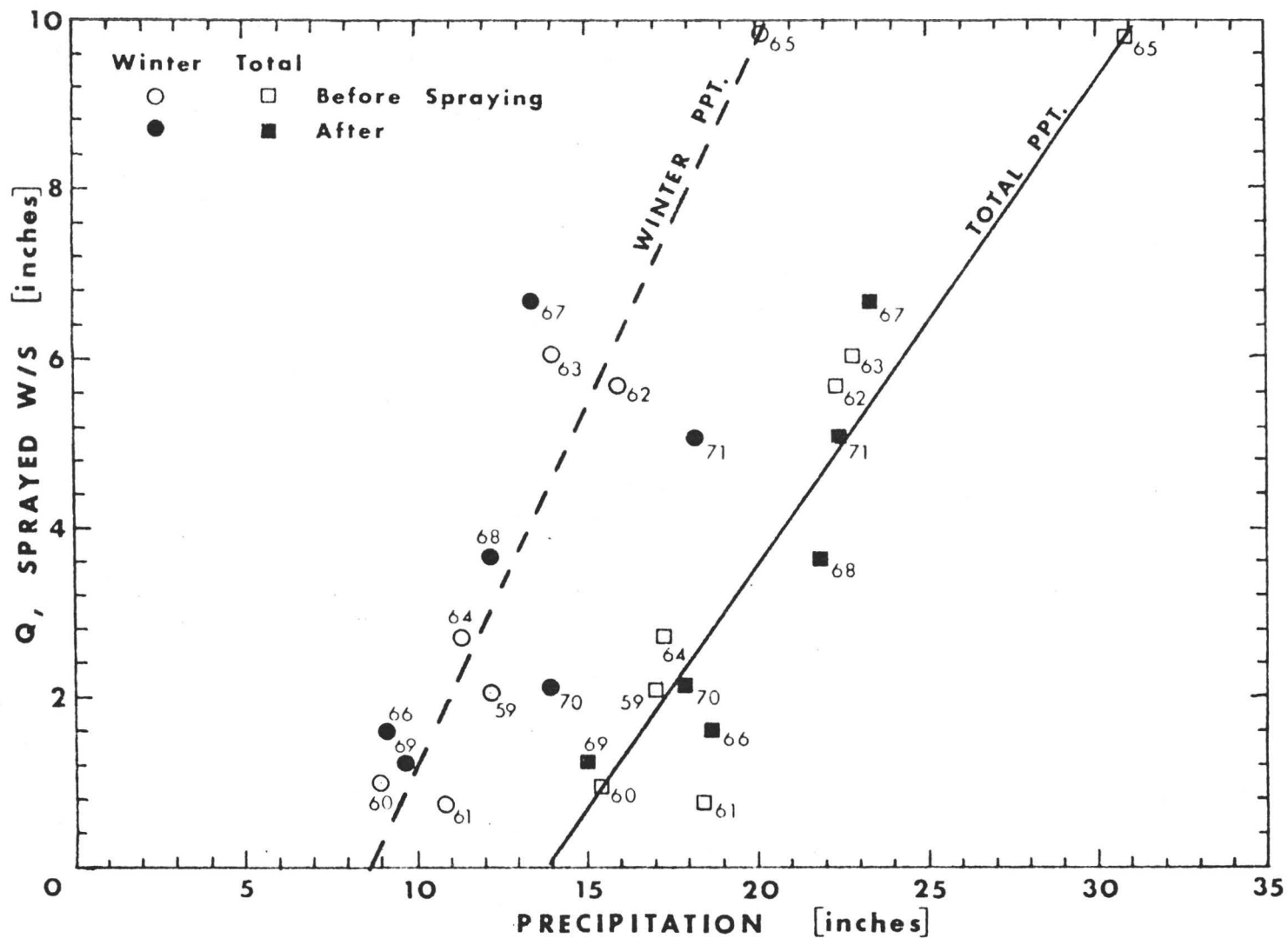


Figure 5. Total annual streamflow (Q) from the sprayed watershed as related to total water-year precipitation, and winter precipitation. Regression lines are fitted to pretreatment data.

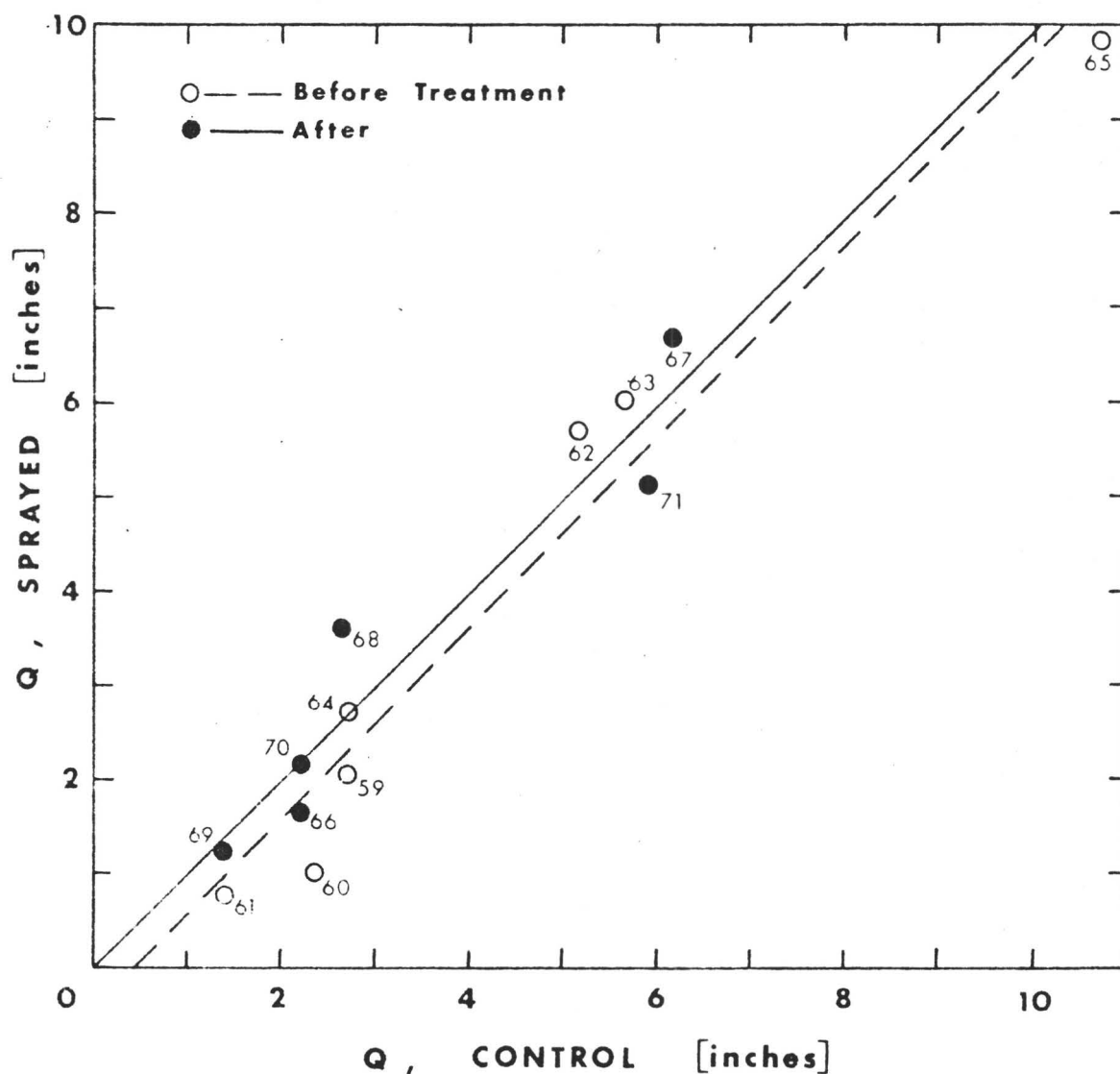


Figure 6. Total annual streamflow (Q), sprayed versus control watersheds. Herbicide was applied on June 29, 1965, by which time 90% of the flow had occurred from the treated watershed. 1965 is therefore used as a pretreatment year. Watershed 2 is used as the control.

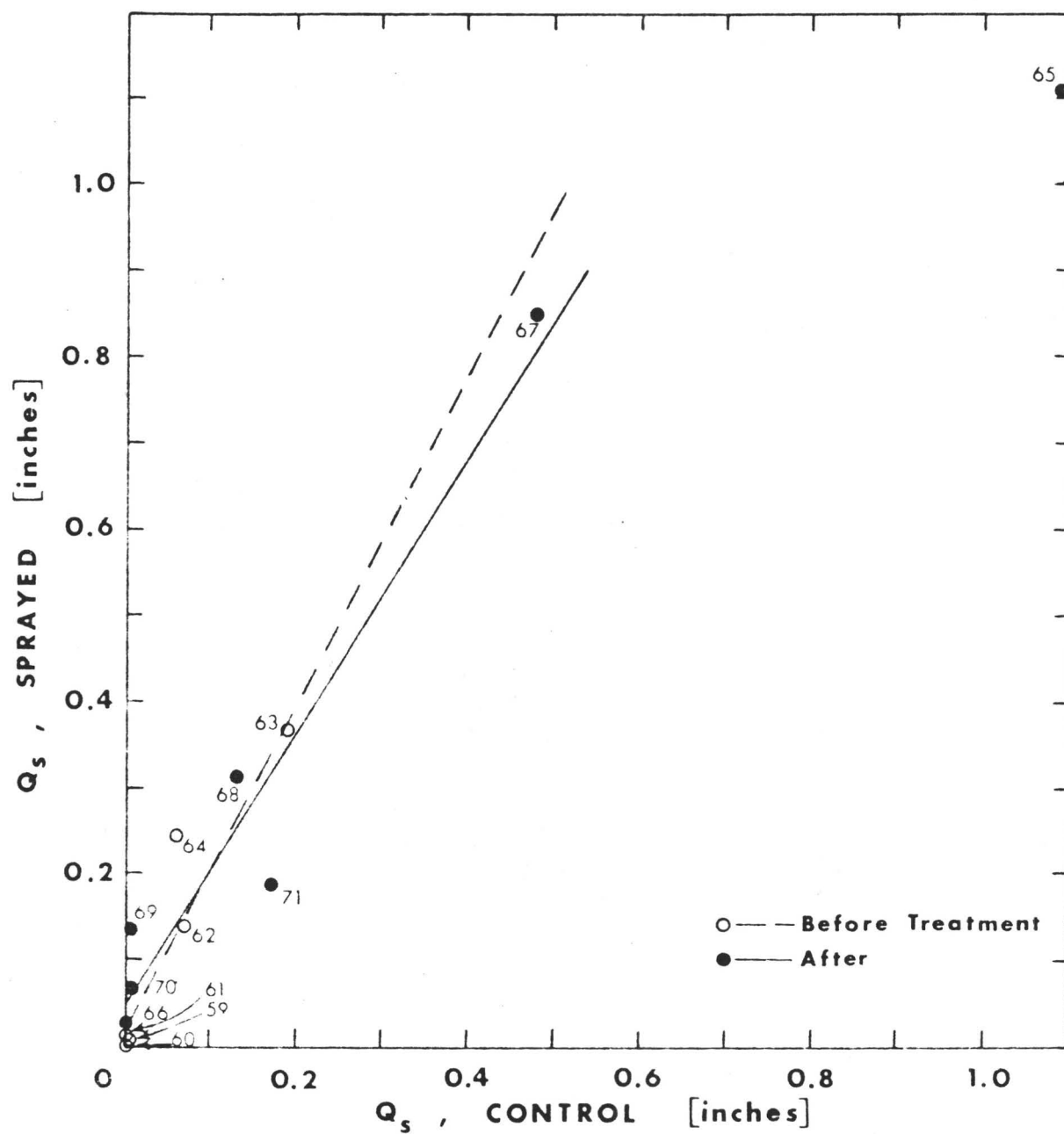


Figure 7. July through September streamflow (Q_s), sprayed versus control watersheds. 1965, the year of treatment, is excluded from both pre- and post-treatment regressions. Watershed 2 is used as the control.

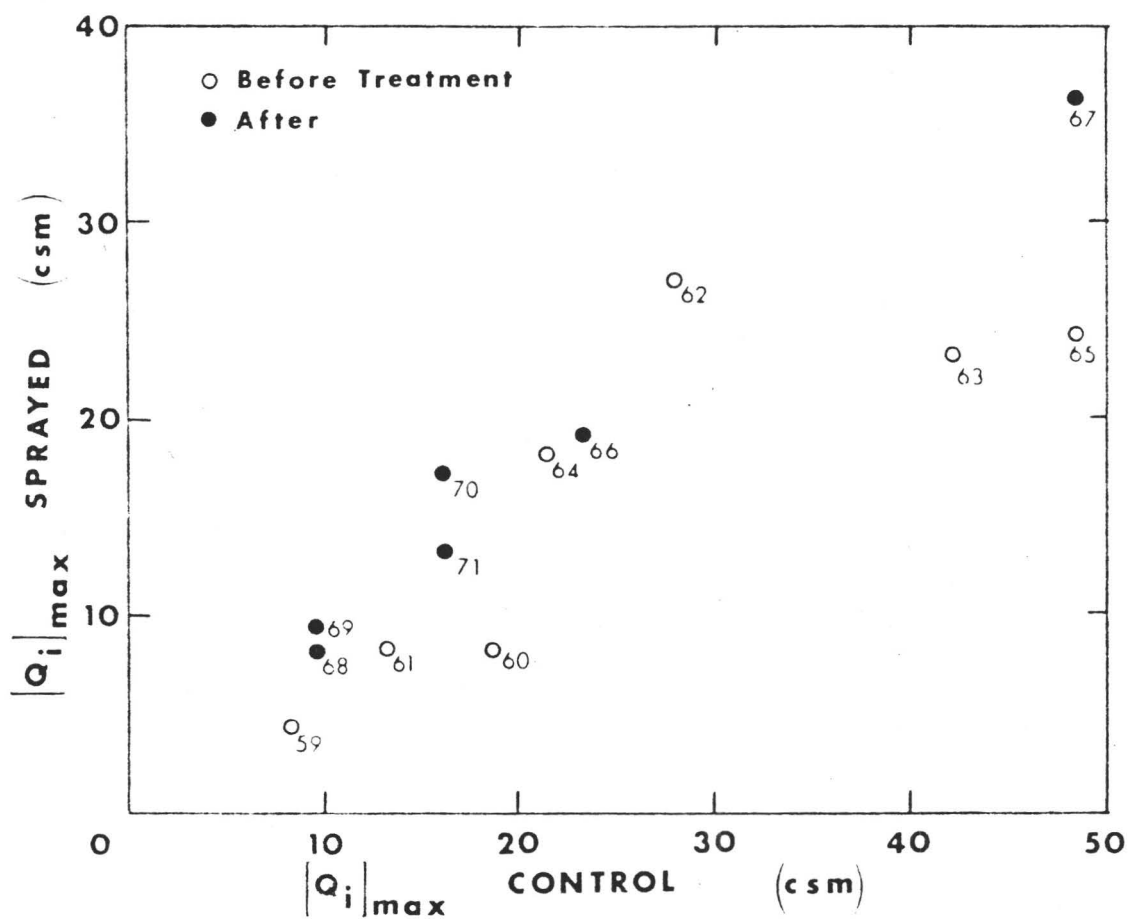


Figure 8. Annual peak instantaneous discharge $[(Q_i)_{\max}]$, sprayed versus control watersheds. Watershed 2 is used as the control.

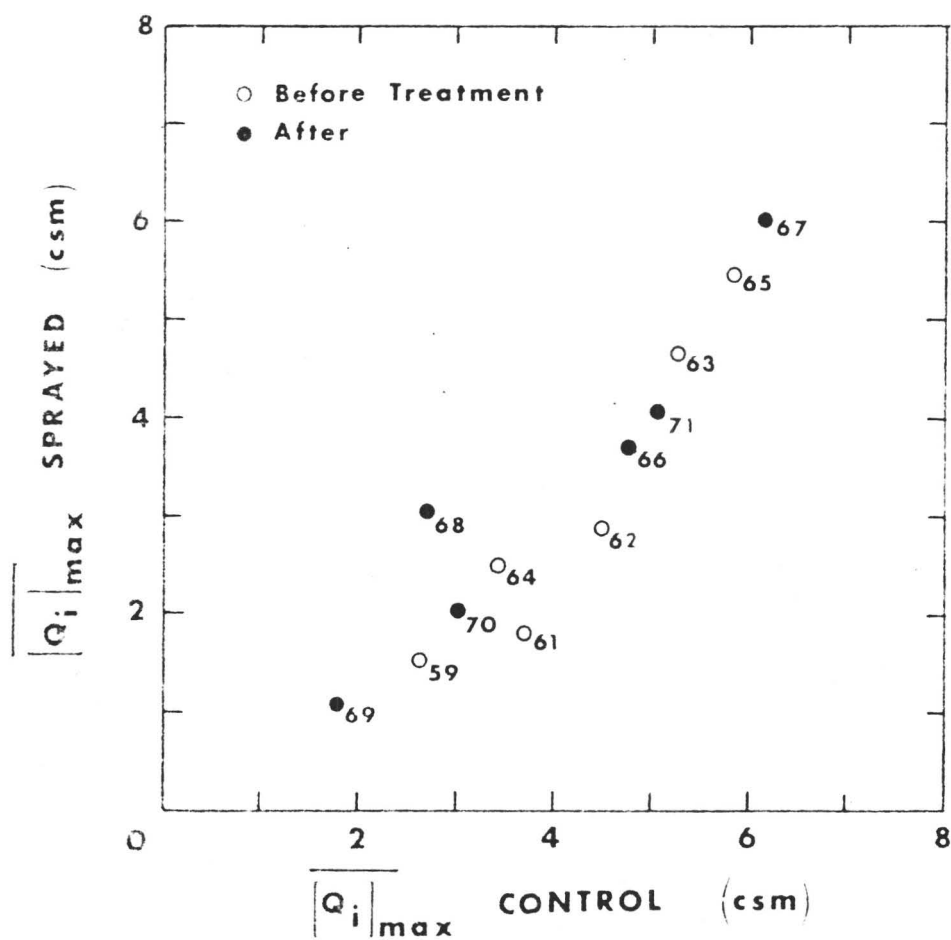


Figure 9. Mean daily peak discharge $[\overline{(Q_i)_{\max}}]$ during snowmelt, sprayed versus control watersheds. 1960 is excluded from this analysis because of incomplete record on both watersheds. Watershed 2 is used as the control.

Table 6. Peak instantaneous discharge (csm) from the three study watersheds

Year	Watershed 1 (0.094 mi ²)			Watershed 2 (0.103 mi ²)			Watershed 3 (0.166 mi ²)		
	Q _{max}	Date	Time	Q _{max}	Date	Time	Q _{max}	Date	Time
1959	6.27	6-30	1330	8.11	6-4	1250	4.16	6-5	1640
60	25.18	5-10	1500	18.52	5-9	1400	8.21	5-9	1500
61	15.45	5-11	0300	13.08	5-9	1640	8.44	5-9	1640
62	34.46	4-17	1030	27.90	5-3	2330	27.01	5-2	0330
63	30.24	5-24	1740	42.17	5-24	1810	23.23	6-2	2230
64	18.20	5-21	1600	21.26	5-19	1800	18.13	5-19	1750
65	26.48	6-16	1630	48.36	6-9	1520	24.14	6-7	1500
- Treatment 6-29-65 -									
66	24.23	5-7	1330	23.18	5-2	1630	19.30	5-3	1800
67	55.34	5-18	0600	48.36	5-17	2200	37.18	5-18	0230
68	10.16	5-29	1650	9.73	5-28	1505	8.02	6-9	1545
69	8.23	5-5	1700	9.38	4-23	1800	9.43	4-22	2100
70	14.93	5-25	1710	15.95	5-25	1630	17.26	5-25	1700
71	23.19	5-31	1730	16.01	6-8	1530	13.07	5-27	1800
Means	22.49			23.23			16.74		

Table 7. Greatest daily mean discharge, in csm, from the three study watersheds

Year	Watershed 1 (0.094 mi ²)		Watershed 2 (0.103 mi ²)		Watershed 3 (0.166 mi ²)	
	$\bar{Q}_{\max}$	Date	$\bar{Q}_{\max}$	Date	$\bar{Q}_{\max}$	Date
1959	1.11	6-30	4.64	6-5	3.07	6-7
60	6.64	5-10	4.94	4-22	2.21	5-9
61	4.11	5-10	7.34	5-10	2.53	5-9
62	12.99	4-21	12.48	5-4	10.63	4-20
63	6.84	5-24	9.16	5-24	6.31	6-4
64	6.40	5-19	8.59	5-19	5.59	5-19
65	11.96	6-16	18.38	6-7	14.29	6-7
- Treatment -						
66	7.69	5-2	9.68	5-2	5.59	5-19
67	15.34	5-18	12.77	5-18	13.13	5-18
68	4.23	5-12	3.31	5-4	4.61	6-9
69	3.23	4-23	5.06	4-23	4.03	4-22
70	5.31	5-25	6.46	5-25	5.48	5-25
71	12.50	5-31	7.38	6-8	7.17	5-27
Means	7.57		8.48		6.51	

Table 8. Suspended sediment (ppm) from the three watersheds, over the period 1959-67, as determined from dip samples

Watershed	Total number of samples	Ave. no.		Maximum conc.	Minimum conc.
		samples per year	Average conc.		
1	59	7	11	87	1
2	86	10	17	214	1
3	100	11	27	746	1

Table 9. Coarse sediment yields (pounds per acre) from the three watersheds, as determined from annual cross-sectioning of the weir ponds

Year	Watershed 1	Watershed 2	Watershed 3
1962	5.7	8.9	6.6
63	3.4	6.8	7.5
64	3.4	1.5	0
65	13.5	12.0	19.8
			- Treatment -
66	1.1	0	1.0
67	3.4	0	6.6
68	0	9.0	1.9
69	0	0	0
70	4.5	4.5	0
71	5.6	0	6.6
Totals	40.5	42.9	50.0
Means	4.0	4.3	5.0

Vegetative Characteristics

Herbage Production.--There was large year-to-year variation in total herbaceous production on the three watersheds (Table 10). On the control watershed (2), grasses comprised an average of 55% of total production (excluding sagebrush), which averaged about 700 pounds per acre (air-dry) over the 12 years of study. Differences in production among the three watersheds reflect the percentage of each covered by relatively shallow rocky soils at the higher elevations.

Before spraying, production was about equally divided among Idaho fescue, "other grasses," lupine and "other forbs" (Table 11).

The year of spraying, total production on the treated watershed was significantly depressed as a result of the reduction in forbs. Production in all subsequent years was significantly increased (Fig. 10), with this increase averaging 38% over the 7 post-treatment years.

Ground Cover (Basal) Area.--Averaged over all years, ground cover (basal area) on the control watershed (2) was 13, 72, and 15 %, for the respective classes Total Herbage, Litter, and Bare + Rock (Table 12). Sagebrush canopy area averaged 13% on the control watershed.

Spraying caused an 84% reduction in sagebrush canopy area (Fig. 11), and a 96% reduction in the number of live sagebrush stems. The only other significant treatment effects on ground cover were an increase in Litter and commensurate decrease in Bare + Rock, on the sprayed watershed (Fig. 12).

Table 10. Herbage production in pounds (air dry) per acre

Year	Watershed 1			Watershed 2			Watershed 3		
	Grasses	Forbs	Total	Grasses	Forbs	Total	Grasses	Forbs	Total
1959	418	257	675	347	188	535	235	137	371
60	---	---	---	---	---	---	---	---	---
61	517	486	1003	490	413	902	502	368	870
62	546	493	1039	442	357	799	336	281	617
63	552	576	1128	427	367	794	320	247	568
64	359	279	638	165	125	291	168	137	304
							--- Treatment ^{a/} ---		
65	477	769	1246	288	410	697	307	116	423
66	773	641	1413	487	306	794	905	143	1048
67	819	745	1564	491	467	958	859	148	1008
68	517	345	863	428	268	696	672	113	786
69	547	339	886	458	296	754	675	120	794
70	415	557	972	332	304	636	470	132	602
71	348	447	795	286	268	554	480	151	631
Means	524	494	1018	387	314	701			
					Before treatment		312	234	546
					After treatment ^{b/}		624	132	756

^{a/} Watershed 3 was sprayed with 2,4-D 38 days before the 1965 production estimates were made.

^{b/} Includes year of treatment (1965).

Table 11. Percent of total herbage production contributed by the different categories of vegetation, averaged over all years

Watershed	Idaho fescue	Poa spp.	Other grasses	Lupine spp.	Other forbs
1	23.0	8.7	19.6	25.6	23.0
2	30.0	6.8	18.3	20.4	24.5
3					
Before spraying	27.3	9.3	20.5	13.2	29.7
Treatment year ^{a/}	29.8	15.6	27.2	8.0	19.4
After spraying	37.9	11.9	33.5	3.9	12.7

^{a/} Watershed 3 was sprayed with 2,4-D 38 days before the 1965 production estimates were made.

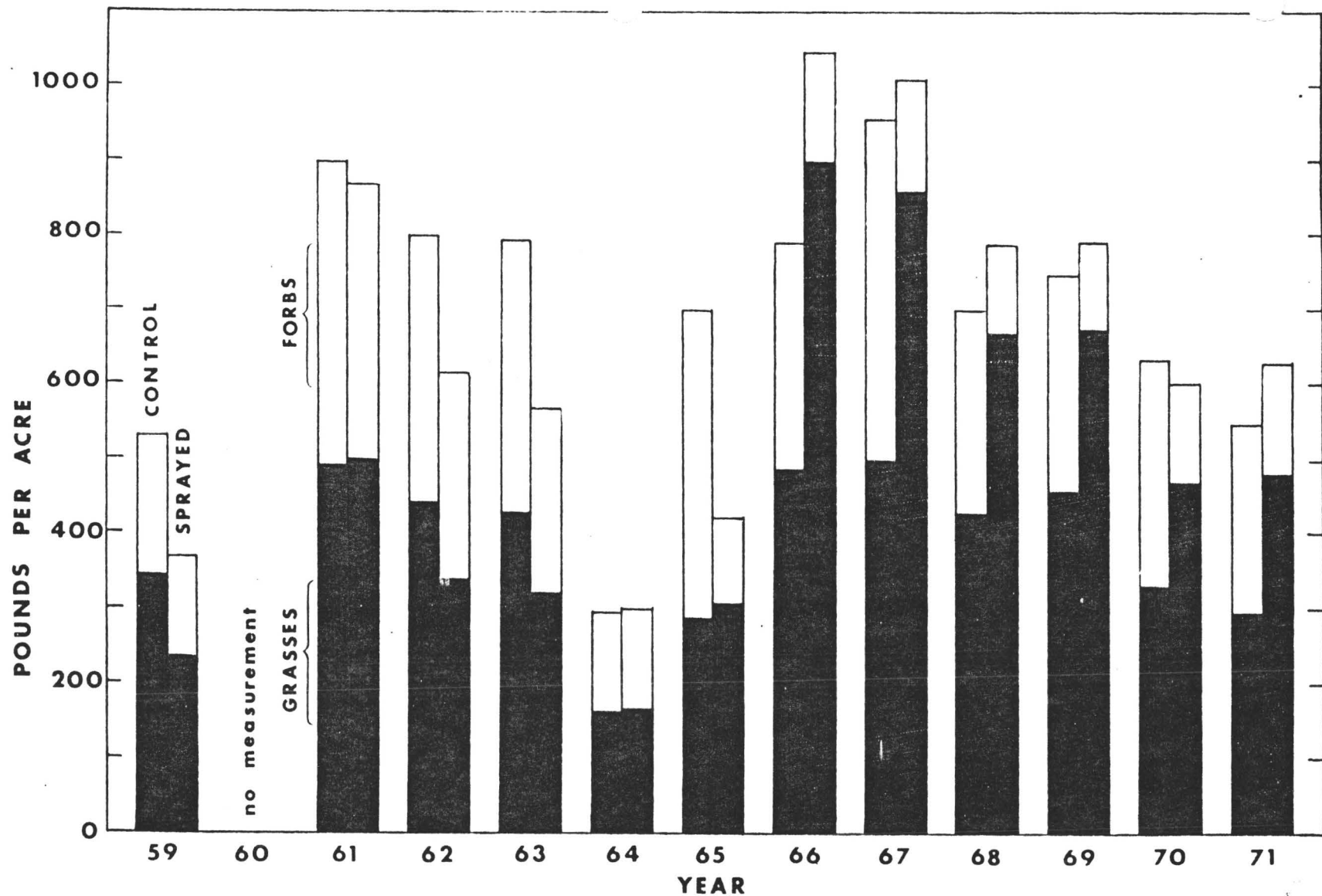


Figure 10. Total annual herbaceous production (air-day) on the sprayed and control watersheds. Herbicide was applied on June 29, 1965, about 40 days before production measurements were made. Watershed 2 is used as the control.

Table 12. Ground cover (basal area) on the three watersheds as measured with a point-quadrat device. Values are in "hits" per 100 points

Watershed	Year	Total herbage	Litter	Bare + Rock	Sagebrush canopy
1	1961	22	66	12	11
	62	13	83	4	12
	63	16	73	11	11
	64	16	74	10	11
	65	14	77	8	11
	66	20	74	6	11
	67	18	76	7	13
	68	25	69	6	12
	69	11	85	4	12
	70	11	85	4	11
	71	14	83	4	11
	Means	16	77	7	11
2	1961	19	64	18	10
	62	11	78	11	12
	63	13	70	17	13
	64	15	69	15	12
	65	10	74	15	13
	66	16	70	14	13
	67	15	71	14	15
	68	18	65	16	13
	69	6	78	15	13
	70	8	78	14	12
	71	12	74	15	13
	Means	13	72	15	13
3	1961	15	68	17	9
	62	13	72	15	11
	63	14	68	18	11
	64	15	67	17	11
	65	9	73	18	4
	66	12	69	19	2
	67	15	67	17	3
	68	17	68	15	3
	69	8	78	14	2
	70	9	77	12	0
	71	12	74	14	0
	Means 61-64	14	69	17	10
	66-71	12	72	15	2

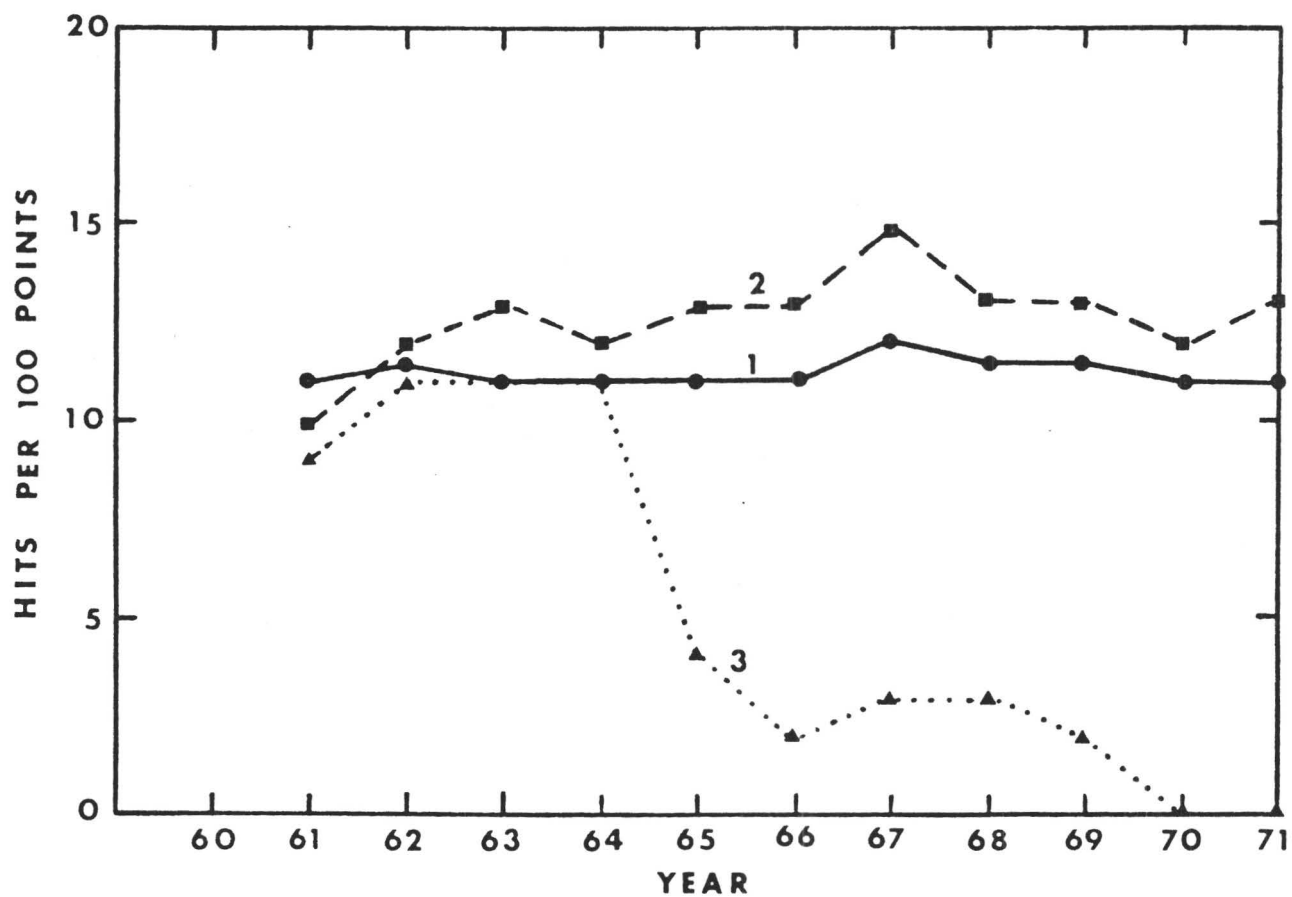


Figure 11. Live sagebrush canopy are on the three watersheds. Watershed 3 was sprayed with 2,4-D on June 29, 1965.

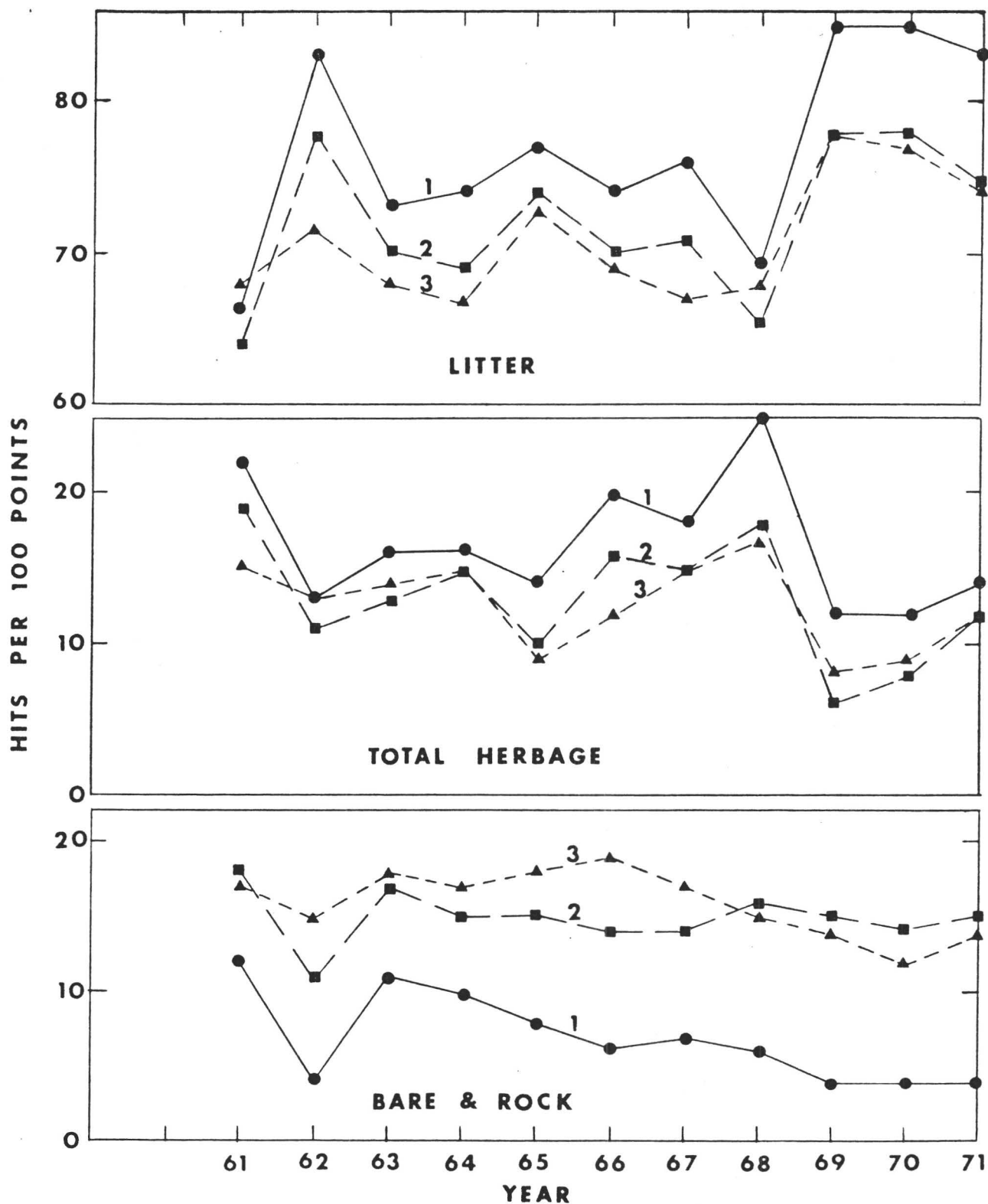


Figure 12. Basal cover on the three watersheds, as measured with a 100-pin point quadrat device. After watershed 3 was sprayed with 2,4-D in 1965, livestock use was excluded from the study area.

Utilization by Elk.--Windswept ridges of the study area were grazed by elk in October and November, and again in early spring (late March to early May). Average utilization from 1960 to 1971 was about 7 elk-days per acre, ranging from 1.4 to 16.0 (Table 13).

Effects of treatment are inconclusive, although the data suggest a decrease in use on watershed 3 the first year after spraying. Utilization on the treated watershed during the last three years of study (4 to 6 years after spraying) was at or above pretreatment levels, compared to the control watershed (Fig. 13).

Table 13. Elk-days use (per acre) on the three watersheds, as estimated from the number of pellet groups counted on 64 1/100 acre plots on each watershed

Year	Watershed 1	Watershed 2	Watershed 3
1960	10.6	10.6	11.9
61	1.8	3.5	5.2
62	2.0	1.4	6.4
63	6.3	4.7	6.0
64	4.8	6.2	7.0
65	4.4	3.0	5.5
66	9.4	7.6	3.1
67	4.6	2.9	2.5
68	8.6	13.8	8.8
69	9.4	7.2	11.4
70	14.8	11.3	14.3
71	7.4	7.7	16.0
Means	7.0	6.7 Before trtmt. After trtmt.	7.0 9.3

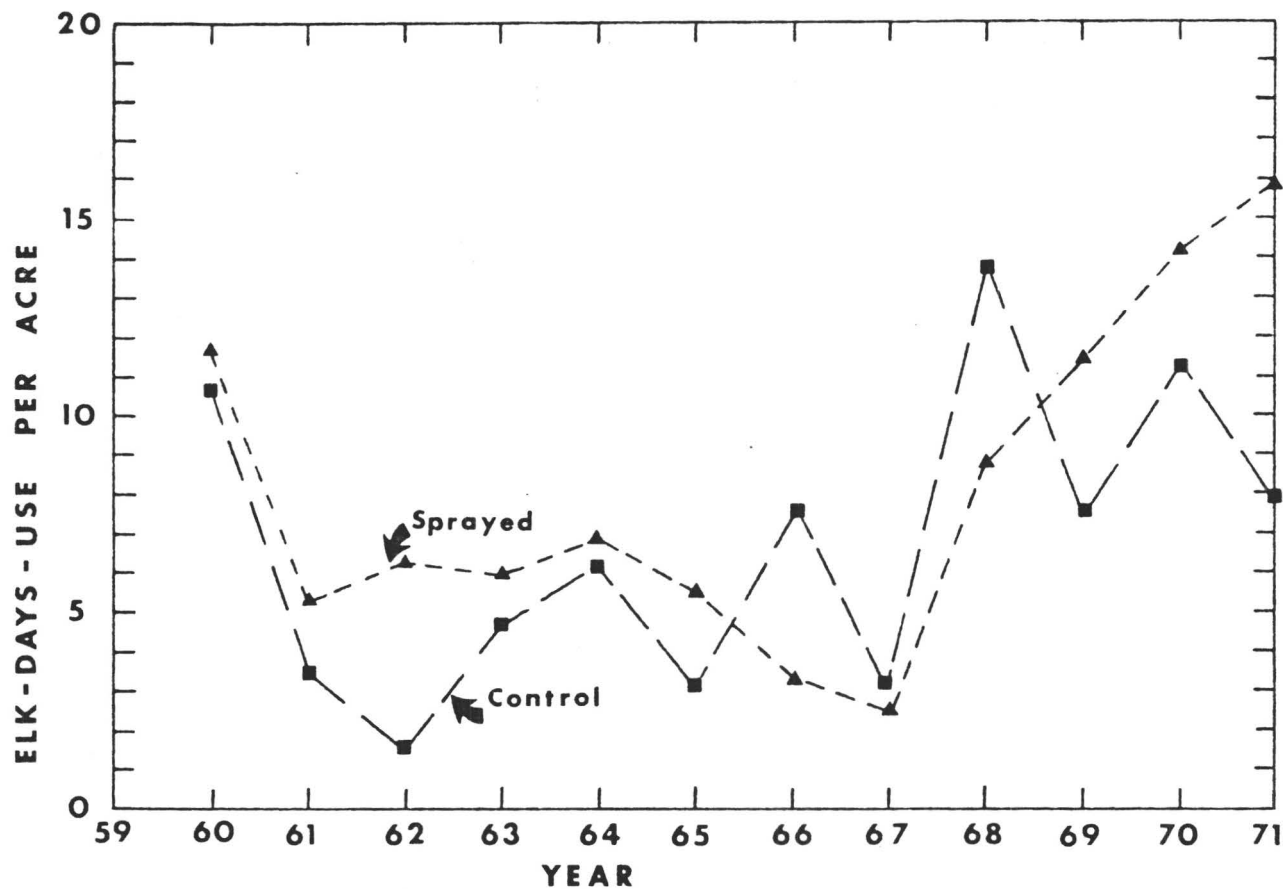


Figure 13. Elk-days use on the sprayed and control (2) watersheds, as determined from pellet-group counts. Following herbicide treatment on June 29, 1965, livestock were excluded from all watersheds.

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